Living Architecture: Making at Architectural Scale

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Abstract

Living architecture offers a means to make at architectural scale without the environmental impact of conventional construction. Along lightweight, temporary scaffolding structures, trees are guided into form. Prominent examples are the living root bridges in Meghalaya, India, just South of Bhutan. During monsoon times, under the world's heaviest rainfall, these bridges transform from constructions of deadwood into living organisms.

This paper advocates for the establishment of dedicated outdoor spaces where makers engage in hands-on experimentation with living architecture, aiming to push the boundaries of this still underexplored domain. Full-scale construction together with nature offers an entirely different experience from drafting and modelling. When it comes to architecture, we all have our stories to share. If invited, many are willing to contribute with either theoretical or hands-on experience. In the given context, an inclusive environment extends beyond humans. If we want to benefit from our co-creators, the trees, it is important to give them creative freedom and to respect their needs.

The author's contribution is his experience with running workshops in Central America and Asia between 2021 and 2023. This study does not attempt to be comprehensive. It certainly is not scientific. It is written from the perspective of a hacker.

Keywords

regenerative development, living architecture, biophilic design, hackerspaces, community

1 Living architecture

Living architecture refers to the construction of functional buildings out of living trees. It is not to be confused with green facades, realized for example with ivy or more recently with vertical gardens where flowerpots cover a wall. These don't serve a structural purpose. In living architecture, the building is the tree.

Examples are the living root bridges in Meghalaya, India. See Figure 1 for an example. In the region with the heaviest rainfall in the world, the climate is corrosive to traditional construction materials such as concrete and steel. During monsoon, strong currents form in the canyons of the jungle. Members of the Khasi and Jaintia communities start by creating a temporary bridge out of bamboo, lashed with cane. If not already there, an Indian rubber tree (Ficus elastica) is planted on a riverbank. Its aerial roots are guided along the bamboo. This is done with the help of trunks of the betel nut palm (areca catechu): An aerial root is put in on one end, then "eats" its way through to the other end. Over decades, the bridge transforms from a construction out of dead wood into an independent organism. It can adapt to changing conditions, and it repairs itself. Living architecture is not so much about the design of a final building, but about the design of a transformation process. That level of thinking for future generations is remarkable from a cultural point of view.

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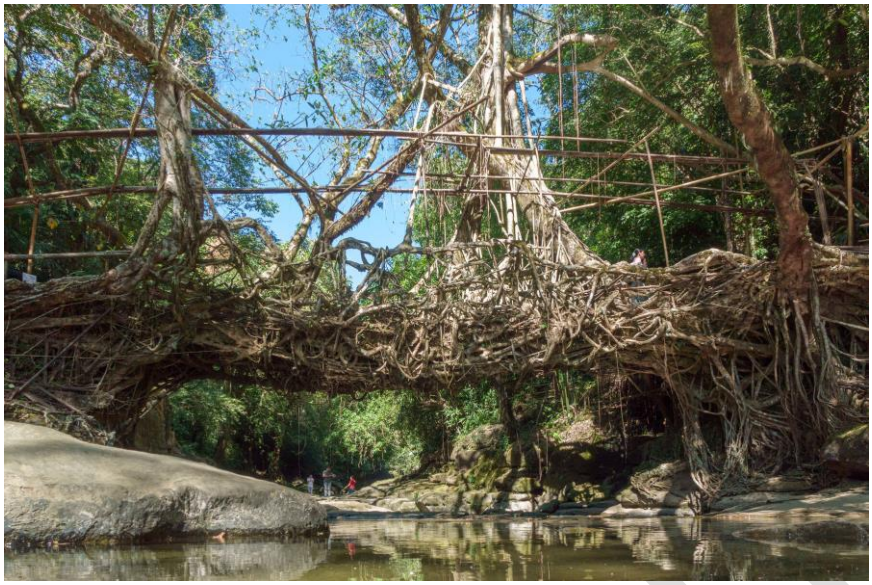
Figure 1: 11/2022, Nowhet, living root bridge, more than 150 years old



In Europe, a familiar example of living architecture are hedges, essentially living fences, or – a level up – the practice of hedge laying. About a century ago, landscape engineer Arthur Wiechula proposed growing houses out of trees (Wiechula, 1926). Many of his ideas were not realistic, even if he was awarded patents for some. More recent and more realistic are the willow houses by Hermann Fritz Block (2018), or the structures of the Office for Living Architecture (OLA, 2023). As part of his dissertation, OLA partner Ferdinand Ludwig investigated trees that grow in Germany regarding how well they inosculate (Ludwig, 2012). Inosculation can be induced for example by screwing or tying branches together.

Ludwig is the architect of various living architecture structures, such as the Plane-Tree-Cube for the 2012 Regional Horticultural Show in Nagold, Germany, together with Daniel Schönle. See Figure 2. On a metal frame, plane tree saplings were planted at multiple levels in pots. The saplings are screwed together. Once they have fused well, the pots and eventually the metal frame can be removed. As with the root bridges, the structure is usable from the beginning. Only over time does it transform into a free-standing organism.

Figure 2: 10/2016, Nagold, Plane Tree Cube by OLA (photo CC BY Nicolás Boullosa, edited)

Living architecture is regenerative (Middleton, et al., 2020) and adaptive. There may be ways to speed up the transformation process by selecting still untested plants, stimulating growth using modern

technology, or even genetically engineering trees (eVolo, 2021). In the meantime, as Khasi architect Aiban S. Mawkhroh mentions, we can think of the process as one of *slow architecture*, comparable to the slow food movement which originated in Italy. We learn from nature by observing how the trees involved assemble themselves and what design decisions they take. They are akin to a third intelligence, next to the architects and the clients. Notably, trees never stop designing. They adapt to external constraints, constantly improving the structure, which is themselves.

2 Architectural hackerspaces

Hackerspaces, sometimes used as an umbrella term to include Fab Labs and maker spaces, opened access to advanced prototyping and small-scale production technology to the public. As Tim Berners-Lee once said, a hacker "is somebody who is creative and does wonderful things". This includes everyone, and especially amateurs. History has shown that amateurs are capable of great innovations. An example of our time is Apple, which was created by tinkerers who hung out in a computer club. More recently, we have seen an explosion in IOT devices, many of which were prototyped in hackerspaces, or using machinery such as DIY 3D printers developed in such spaces. In this paper we use the terms maker and hacker interchangeably.

"Hardware is hard." This saying refers to the development of electronics products as compared to the development of computer software. Crucial to lowering the barrier of entry is not only access to machinery but also the practice of sharing knowledge with an open-source mindset.

Architecture is harder. Land is a scarce resource, especially in densely populated areas. Building codes tightly regulate what owners can do with their land, not exactly encouraging exploration. Conventional construction materials and tools are expensive due to their size and volume. A failed experiment at architectural scale is generally much more harmful to the environment than a failed print of a desktop scale object in a hackerspace.

Thereby amateurs are largely excluded from innovating architecture and construction. Yet, judging by their contribution in the world of electronics technology, we can assume that amateurs are able to provide considerable value, if only given the chance to play, to understand, and to try out new solutions. We interact with architecture every day. It is a field in which we are all experts to some extent.

Living architecture provides a means to explore architecture in an inexpensive, resource friendly and non-harmful way. The material, trees, generally is cheap. Using photosynthesis, it assembles itself from carbon in the air. Failed experiments benefit the environment. As arborsculptor Richard Reames mentioned in an interview with Ludwig (de Bruyn, et al., 2009; translated from German): "Since I only used a few of [the trees I bought for sculpting], I now have a little forest in my garden."

Members of an architectural hackerspace use their entire bodies when building. The challenges faced are real. In an interdisciplinary exchange, engineers are encouraged to learn about botany, and botanists are encouraged to learn about engineering. Our natural teachers are the trees. We learn how they solve engineering problems at wood junctions (Middleton, 2022). We observe their approach form finding (Otto, 1988).

Our requirement is access to land with favorable building codes, the right climate, and the possibility to foster good community.

3 Metrics

For analyzing locations for their suitability as a hackerspace for living architecture, we look at metrics:

- *Climate zone:* The climate zone, according to the Köppen-Geiger classification (Kottek, et al., 2006).

- *Plant material:* Living root bridges are made of Ficus elastica, a type of strangler fig. However, there are other plants ready to be explored for living architecture. Good biodiversity plus good growth conditions are beneficial for our undertaking. They receive a positive rating.
- *Scaffolding material:* The scaffold is the initial structure, along which trees are guided. We rate the availability and price of sustainable materials such as bamboo.
- *Creative freedom:* Tight building codes can make it hard to experiment and to use what we build how we want. In some locations, there are organizations who have the necessary permits and with whom we may be able to collaborate. Favorable building codes or building codes that are not enforced lead to a positive rating, so do partner organizations that give us the necessary freedom. It needs to be pointed out that living architecture to some extent allows us to experiment on farmland. I.e., until we want to move into what we built and live there.
- *Accessibility:* If land is remote and hard to access, it will be harder to build a community. Land easily accessible for potential hackerspace members receives a positive rating.
- *Experiential factor:* If we can use what we build, then it is more likely that we create something that is useful for others as well. This means, if we can trial our own constructions, for example live in them, then this gets a positive rating.

Most metrics are hard to quantify precisely. Therefore, except for the first metric, rating is reduced to four simple values:

-	negative
0	neutral
+	positive
?	unknown, or too hard to judge

When looking at the quality of existing hackerspaces, there are highly subjective additional factors at play, such as community and harmony, even ideology. These are difficult to quantify and therefore left out from this study.

4 Survey

The focus is on locations that the author has personally visited or with which he has been in contact. We look at existing hackerspaces and spaces that could be available for collaboration. Naturally, this list is incomplete. It should be seen more as a template for an ongoing survey of potential locations for living architecture hackerspaces.

Climate zones are based on data from Mindat.org (2023), where:

- Cwa: Monsoon-influenced humid subtropical climate
- Af: Tropical rainforest climate
- Am: Tropical monsoon climate
- Cwa: Monsoon-influenced humid subtropical climate
- Cfb : Temperate oceanic climate

Metrics are summarized in Table 1 and detailed below.

Table 1: Metrics of locations in survey

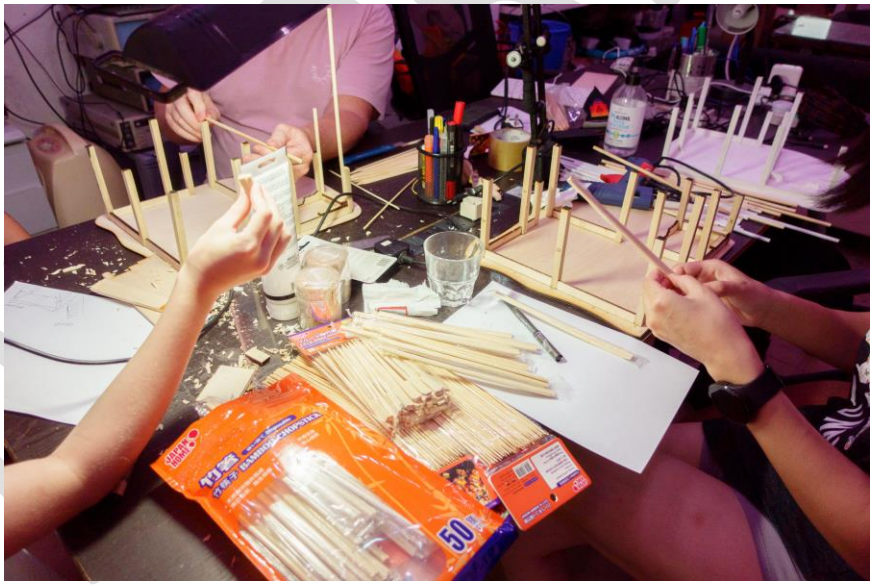
Location	Climate zone	Plant material	Scaffolding material	Creative freedom	Accessibility	Experiential factor
Hong Kong	Cwa	+	+	-	+	-
Lancetilla	Af	+	+	+	0	0
DSA	Am	+	0	+	0	+

Meghalaya	Cwa	+	+	?	-	?
CHT	varies	+	?	+	0	+
CCC	Cfb	-	0	+	+	+

4.1 Hong Kong

High quality construction ready bamboo is easily available because it is used as the primary scaffolding material in the city. The climate is conductive to the growth of strangler figs as well as to other tropical plants useful for experiments, such as betel nut palms. Known as the city with the highest property prices in the world, it is notoriously hard and costly to obtain land. In the past, this led to the construction of squatter houses. An urban example was Kowloon Walled City, a massive unplanned settlement with its own rules. Nowadays there are tight regulations, and they are enforced. Still in remote locations, one can find improvised constructions such as geodesic domes. Generally, these are either temporary buildings for illegal parties, or they are built by villagers who have the right connections and whose doing is tolerated. The author has been in contact with Ark Eden, founded by Jenny Quinton. She has a personal interest in living architecture, and she has a site. However, this site would be for one specific project, less so for free experimentation. Accessibility in Hong Kong is excellent due to its compact size and good public transport. From 7.5 million well-educated people it should be possible to build a lasting community. An example of such a community is the Dim Sum Labs hackerspace, where the author organizes the series Bamboo & Banyans. See Figure 3 for a photo taken at the recent session Architectural Protoyping (2023). Constrained to a small office on the top floor of a high rise, there is, however, no capacity to run architecture scale experiments.

Figure 3: 07/2023, DSL: Architectural prototyping in the series Bamboo & Banyans



4.2 Honduras: Lancetilla

Lancetilla (2023) is the national botanical garden of Honduras. In 2022, the author got in contact with Delmer Jonathan Hernandez Sosa, its then new director. His background is bat research, and he has an interest in the food sources of this species (Matamoros Ortiz, et al., 2023). The garden has a variety of strangler figs, an ideal material for living architecture. Bats eat their fruits and deposit seeds on top of other trees.

The realization of a living pavilion for the 100th anniversary of the garden in 2026 was discussed, yet so far is limited by funding. There is a surplus of high-quality construction wood from trees that were destroyed by the hurricanes Eta and Iota. Freshly cut bamboo is available as well, though methods of preservation are not cultivated. Accessibility for people that may form the basis of an architectural

hacker space is limited. Nearby Tela is small. It is unlikely to provide enough interested people to build a community around this very specialized field.

The garden is part of UNACIFOR, the forestry university in Honduras, located 180 km away. Students regularly visit, for several days or weeks at a time. While a pavilion is a functional structure that can be experienced, it does not seem feasible for makers to set up arbitrary structures and to live in them. There are also considerations concerning personal safety in a country known for high rates of violent crime.

In July 2022, Together with Garivani and Dackiw, the author organized a living architecture workshop with garden staff. Various Ficus cuttings, seeds, and one sapling were sampled, then planted on structures made of freshly cut bamboo (Klee, 2022a). See Figure 4.

The author learned about Lancetilla when visiting the special economic zone Próspera, which operates within the constitution of Honduras. It has its own legislation when it comes to the building code. Builders can select from several established codes imported from other legislations worldwide. However, land is scarce. Setting up a place for experimentation would probably be expensive, although in theory it is possible to obtain outside land and incorporate it into the zone.

Figure 4: 07/2022, Lancetilla: Workshop with garden staff (director on the left)

4.3 Sri Lanka: DreamSpace Academy (DSA)

DSA (2023) is an NGO that helps young, often disadvantaged people to realize their dreams in the fields of technology, science, arts, and media. It consists of a school building, a workshop with CNC machines in containers, and a dorm. There is additional land available, which could provide space for experimentation with living architecture. Yet, there is no knowledge in the field of construction at that scale. This would need to be built up, perhaps with visitors from outside as part of the newly set up hacker in residence program.

Located at the last stop of the train running from Colombo, DSA is not exactly easy to reach. Compared to other locations in Sri Lanka, Batticaloa is underdeveloped when it comes to tourism. There is the desire to attract more visitors. Regenerative design in the form of living architecture offers the opportunity to avoid the negative impact on the environment that often comes as a side effect of tourism.

Scaffolding material is available, ideally in the shape of recycled wood. There is no culture of using bamboo for construction. A common belief is that bamboo is an invasive species harmful to the island's ecosystem. Others say, this is a myth. Sri Lanka is known for its high level of biodiversity. As such, there are many plants to experiment with. It must be said that the western part of the island with higher

humidity is more conductive to the growth of strangler figs. Building codes are not necessarily enforced in Batticaloa, the author was told. This enables creative freedom and the possibility to set up experimental structures to live in.

In July 2022, during Dinacon, the author ran a workshop at DSA: Fig, Ficus, Fighouse! (Klee, 2022b) The following year he returned to follow up with two more workshops, see Figure 5. The design outcome was that for a living staircase into the sky, which can be grown step by step. It remains unrealized.

Figure 5: 05/2023, DSA, stress testing during workshop (photo by DSA staff)

4.4 Meghalaya, India

Meghalaya is home to the living root bridges and the expertise surrounding their construction and maintenance. It is conceivable to set up a camp where guests can learn about techniques of living architecture and run experiments. A potential partner is the Living Bridge Foundation. Materials needed are readily available. Access is hard for the wider hacker scene, however. It requires flying, or from other parts of India taking long distance trains, then getting by taxi to remote locations. Accessibility challenges building a grassroots community that lasts longer than just for specific courses or events.

On the other hand, there is a strong local community relating to living root bridges. Nowadays driven by competition for tourists, it explores non-conventional ways of extending existing bridges and building new ones. Upon close inspection, it perhaps is not that different from a hacker community.

The Living Bridge Foundation and Atelier A+ Architects provided local know-how for the construction of the 2022 Living Root Pavilion, a project of the North Eastern Hills University and the Technical University of Munich (The Meghalayan Bureau, 2022). See Figure 6.

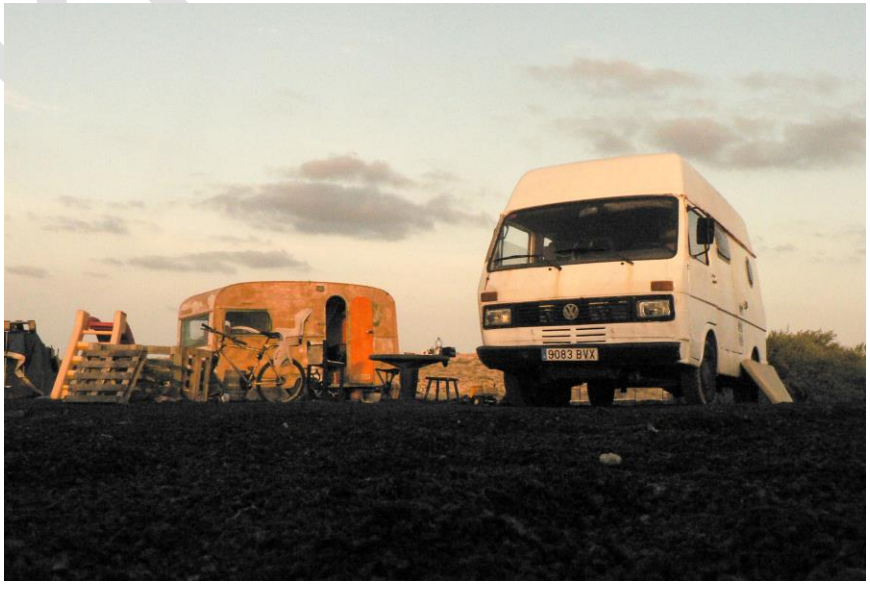
Figure 6: 2022/11, NEHU, Shillong, completion of the Living Root Pavilion

4.5 Canary Islands: Cyber Hippie Totalism (CHT)

CHT (2023) was founded by David Potocnik, who coined the term hackbase. Generally, hackerspaces have strict rules to prevent members from sleeping there. A hackbase, on the other hand, explicitly invites members to live in it. When the author visited in 2014, CHT was in the Canary Islands. Initially in a rented house, it later moved outside (see Figure 7). There was discussion about experimental structures. Yet, there was no permanent land for setting up such structures. With their many climate zones, the Canary Islands provide a great level of biodiversity and plants to experiment with. The islands are easy and cheap to reach from Europe mainland with its striving hacker scene, albeit only by medium to long distance flights or ferry. In the meantime, CHT has moved to other places following an apparently nomadic concept.

A nomadic lifestyle may at first look incompatible with living architecture. However, with a hacker mindset, it is conceivable to plant structures in places that are not declared as construction land. Possibly years later, on another trip, one would return to using them. The challenge, for one, would be to design scaffolding structures that are based on fully biodegradable materials. That way they can be left alone without having to clear them up later. In addition, the architectural growth process needs to happen mostly unattended.

Figure 7: 12/2014, Lanzarote, Canary Islands, Cyber Hippie Totalism hackbase



4.6 Germany: Chaos Communication Camp (CCC)

Chaos Communication Camp is a quadrennial hacker meeting organized by Germany's Chaos Computer Club. In 2015, the author set up a live streamed interactive installation about collaborative architecture (Wir bauen, 2015). See Figure 8. There are other camps, including the burner festivals, where people set up temporary and unconventional structures. "Building codes" are favorable. Structures will be experienced. Accessibility to the hacker community is excellent. However, it is unrealistic to grow anything at such an event. It would be different if the event was always in the same spot, if it was possible to keep what has been set up, and if there was some maintenance in between the years.

Figure 8: 08/2015, Ziegeleipark Mildenberg, Wir bauen

4.7 Unrated

What follows are two locations that the author sees as important examples, but which he has not visited. As such, their rating is better left to people who have experienced them.

Institute of Intuitive Technology and Bio-Architecture (Tibá)

Tibá (2023) sits in the Brazilian jungle. It was founded in 1987 by Rose and Johan van Lengen. To the author's understanding, which was formed by attendance of a workshop held by van Lengen, the institute's mission is research and teaching of design and construction techniques that can be applied by individuals without training in architecture or construction. Recipes can be found in the book The Barefoot Architect (van Lengen, 2007). Tibá is worth studying as an example of a laboratory for vernacular architecture in humid subtropical climate.

Open Source Ecology (OSE)

The idea behind OSE is the Global Village Construction Set, which basically allows recreation of civilization from scratch (Jakubowski, 2011). Various tools have been created in this endeavor, including heavy machinery for construction. They are fully documented so that they can be replicated elsewhere in the world. In recent years, the Seed Eco Home (2023), an open-source house, has been developed. Its advantage is low cost and quick building time.

The focus of OSE seems to be more on developing practical tools for immediate application, less on fundamental research. Therefore, living architecture may not quite fit into the concept. But tools and know-how from the project are certainly useful for realizing experimental buildings elsewhere.

5 Conclusion / Outlook

Universities place a strong focus on fundamental research. In the case of living architecture, it is a form of material science, although there are many aspects. In contrast, while fundamental research is not out of the question, in hackerspaces we focus more on fun and on hacks that improve the lives of ourselves and that of our peers. Occasionally, products materialize from our exploration. They are the basis for startups.

In fact, in what could be called our "mission to the moon", products may result from technical needs in the process of working with living architecture. For example, to monitor growth, measurements need to be taken. There is room for open-source hardware solutions. Photogrammetry is now a popular method for analyzing living root bridges from a structural engineering point of view (Middleton, et al., 2019). How does one regularly do 3D scans? Perhaps drones could be programmed, or a volumetric camera could be assembled from dozens of small and cheap camera modules that are permanently mounted in place. Another example comes from the field of biology: What bio hacks could be used to stimulate and accelerate growth?

Limiting the scope of a hackerspace to living architecture has the advantage that we are working with regenerative technology. If well designed and executed, our experiments are beneficial to the environment. They are not degenerative as with other technologies, such as conventional 3D printing. Yet, we may not want to limit ourselves to a specific regenerative technique. An alternative approach is the definition of an outcome, and letting the people's creativity decide how to best get there.

In the meantime, living architecture provides a good entry point to generative design. As can be seen by the vast number of visitors to the living root bridges, it has a wide appeal. It encourages thinking outside of the box of conventional construction.

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Except where noted otherwise, photos were taken by the author.

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